

PATENT
450117-03316

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
APPLICATION FOR LETTERS PATENT

TITLE: MULTIBAND RADIO SYSTEM AND METHOD FOR
OPERATING A MULTIBAND RADIO SYSTEM

INVENTORS: Janos ENDERLEIN, Besma KRAIEM

William S. Frommer
Registration No. 25,506
FROMMER LAWRENCE & HAUG LLP
745 Fifth Avenue
New York, New York 10151
Tel. (212) 588-0800

Description

1 This invention is related to multiband radio systems, in particular to an arrangement for isolation of signals between a receiving and a transmitting branch thereof, further particular to a high frequency multiband radio system, and to a method for operating a multiband radio system.

5

Generally, within a conventional modern Time Division Duplex (TDD) arrangement, as shown in Fig. 4, each of said receiving and transmitting branches comprises at least two selectable radio frequency filters, since more than one frequency band is supported. Within each of said branches said radio frequency
10 filters are arranged in parallel and they are selectable by at least one pair of multiplexer switches. Said radio frequency filters comprise passband functions, whereby, within each of said branches, said passband functions of each of said radio frequency filters are responsible for a given frequency band being different from respective frequency bands of each of the other radio frequency filters. Said
15 pairs of multiplexer switches are actuated by means of a band selection signal. Further, in operation, in both of said receiving and transmitting branches signals pass through radio frequency filters, the properties of which are suited for one and the same frequency band, i.e. the band selection is done by switching discrete band selecting filters 'on' or 'off' the RF signal path of the receiving
20 branch and the transmitting branch. Said receiving branch further comprises a demodulator and said transmitting branch further comprises a modulator for down/up-conversion of the received RF signal to IF and the IF signal to be transmitted to RF on basis of a carrier signal supplied from an oscillator. Said carrier signal is fed from said oscillator to either said demodulator or said modulator via
25 a receive/transmit switch which, in turn, is actuated by a receive/transmit selection or control signal.

Further detail of this conventional arrangement as shown in Fig. 4 will be discussed in detail lateron. Since switches for RF in GHz range have typical
30 isolation values of less than 25 dB, in operating such a TDD arrangement there occurs leakage of the receiving signal from the transmitting branch to the receiving branch via the transmitting antenna of said transmitting branch. However, for high sensitive radio systems, in particular in the high frequency range, such as the HiperLAN2 (H/2) or IEEE802.11 (802.11) the RF leakage has to be less than the RX sensitivity of e.g. -85 dBm.

- 1 In order to overcome this leakage in this conventional arrangement, there are
provided additional switches to loads via which signals are supplied to the
transmitting branch, being activated in the receiving mode of operation of said
arrangement which cause a higher attenuation of the signal to be transmitted in
5 the transmitting mode. In particular, the oscillator is switched 'off' (out) from the
modulator (mixer) of the transmitting branch and the IF path is switched 'off'
(out) from the transmitting branch.

- Therefore, this conventional arrangement shows two disadvantages, namely
10 higher cost in production because of said additional switches and unwanted
signal attenuation.

A somewhat similar arrangement is disclosed in EP 0 741 463 A2.

- 15 It is an object of this invention to improve said conventional arrangement so that
better isolation is achieved at lower cost in production and with no additional at-
tenuation in the transmitting signal path caused by measures for isolation. It is
another object of this invention to modify operation of said multiband radio
system such that said isolation of signals is improved in the receiving mode.

- 20 This object is solved by a Multiband Radio System according to claim 1. Pre-
ferred embodiments thereof are defined in claims 2 to 5. The method to operate a
Multiband Radio System according to the invention is defined in independent
claim 6. A preferred embodiment thereof is defined in claims 7.

- 25 Therewith, a multiband radio system according to the present invention which
comprises a receiving branch and a transmitting branch respectively supporting
more than one different frequency band, is characterized by a receiving/
transmitting filter selector controlling radio frequency filters included within
30 said receiving branch and said transmitting branch, respectively, in receiving
mode so that radio signals of a frequency band which are passed through in the
receiving branch are blocked in the transmitting branch.

- Further, a method for operating a multiband radio system comprising a receiving
35 branch and a transmitting branch according to the present invention is charac-
terized by controlling radio frequency filters included within said receiving
branch and said transmitting branch, respectively, in receiving mode so that ra-

- 1 dio signals of a frequency band which are passed through in the receiving branch are blocked in the transmitting branch.

5 Therewith the two disadvantages of the conventional arrangement, namely higher cost in production because of said additional switches and unwanted signal attenuation, are eliminated. In particular, according to the present invention, no unwanted signal attenuation occurs while maintaining less leakage, since the additional switches which are necessary according to the prior art, are obsolete according to the invention.

10

According to a preferred embodiment, this invention provides, additionally to said conventional arrangement described above, a receiving/transmitting filter selector, being inputted by a receive/transmit control signal and by a primary band selection signal. Secondary band selection signals are outputted and
15 transmitted to said branches. Further, said additional switches of said conventional arrangement switching input signals of the transmitting branch to loads are omitted. Additionally, said multiband radio system is operated in its receiving mode in such a way that signals that like to pass through said filters in both of said branches are blocked in the transmitting branch as both filters
20 through which said signals like to pass through are responsible for different frequency bands, i.e. have passbands in different frequency bands.

The preferred embodiment according to the present invention operates in a way that, when being in receiving mode, a filter in said receiving branch responsible
25 for a first frequency band is selected and a filter is selected in said transmitting branch being responsible for a second frequency band being different from said first frequency band. This results in that, when high frequency signals of a first frequency band are received, said high frequency signals cannot interfere with each other, as they are blocked within said transmitting branch so that, in the
30 receiving mode, there occurs almost no leakage between the branches.

Further, it is cheaper in production to provide an arrangement with said receiving/transmitting filter selector rather than to provide several additional switches and loads according to said conventional arrangement.

35

The present invention will be better understood from the following description of an exemplary embodiment thereof taken in conjunction with the accompanying

1 figures, wherein

Fig. 1 shows parts of a multiband radio system according to a first embodiment of the present invention.

5 **Figs. 2 and 3** show second and third embodiments of the present invention, each of them partially, and

Fig. 4 shows a conventional arrangement.

Fig. 4 shows a conventional arrangement, as briefly discussed in the
10 introductory part of this specification. In the upper half of figure 4 there is shown a receiving branch RX, indicated by dashed lines. Said receiving branch RX comprises, among other elements, first and second radio frequency filters RF1, RF2. Each of said radio frequency filters RF1, RF2 is a stop band filter. Each of these radio frequency filters RF1, RF2 is dedicated to pass through
15 signals being part of a specific frequency band, whereby the frequency band associated with the first radio frequency filter RF1 is different from the frequency band associated with the second radio frequency filter RF2. For example, the filters might support the upper and lower frequency band of H/2 or 802.11a. Said radio frequency filters RF1, RF2 are arranged in parallel to each
20 other. They are separated from each other and selectable by a pair of multiplexer switches RSW1, RSW2.

Within said receiving branch RX there is also arranged a demodulator RSW for downconverting a received and filtered signal into the Intermediate Frequency
25 range. Said demodulator RSW receives a carrier signal output from an oscillator CS via a receive/transmit switch RTSW, which, in turn, is activated by a receive/transmit control signal RTCS. If said receive/transmit control signal RTCS is in the state "receive", then it forces said receive/transmit switch RTSW to pass said carrier signal to the demodulator RSW to allow a received signal to
30 be demodulated to the IF. Otherwise, no demodulation is performed.

Said pair of multiplexer switches RSW1, RSW2 is activated by means of a band selection signal BSS. When said band selection signal BSS is in a first state, the multiplexer switches MSW1, MSW2 are switched into a first state so that a
35 received signal is allowed to pass through said first radio frequency filter RF1 in the receiving branch RX. Otherwise, said multiplexer switches MSW1, MSW2 are switched into a second state so that a received signal is allowed to pass through

1 said second radio frequency filter RF2 in said receiving branch RX.

In parallel to said receiving branch RX there is arranged a transmitting branch TX. It comprises similar elements like the receiving branch RX, as described
5 above: a pair of radio frequency filters TF1, TF2, a pair of multiplexer switches TSW1, TSW2, and a modulator TSW for upconverting a signal to be transmitted from IF to RF (Radio Frequency). The operation of these elements in the transmitting branch TX also corresponds to the operation of the respective elements in the receiving branch RX.

10

Further, the carrier frequency output from the oscillator CS is fed to the transmitting branch TX via the receive/transmit switch RTSW and a first additional switch SW1, and the IF signal is input to the transmitting branch TX via a second additional switch SW2.

15

Said band selection signal BSS is, as already explained, fed to each of said multiplexer switches RSW1, RSW2, TSW1, TSW2 in both of said branches RX, TX. Its purpose is to select, in each of said branches RX, TX, an appropriate radio frequency filter (either RF1 and TF1 or RF2 and TF2) according to the
20 selected frequency band, within which a signal is to be received or to be transmitted. To make an example: if a signal within a first frequency band is to be received, all of said multiplexer switches RSW1, RSW2, TSW1, TSW2 are switched into a first position, so that signal paths between the multiplexer switches RSW1 and RSW2 and, respectively, between TSW1 and TSW2 take place
25 via said first radio frequency filters RF1 and TF1. The same occurs in case of transmitting a signal being within said first frequency band. However, if a signal being within a second frequency band is to be received or transmitted, said multiplexer switches RSW1, RSW2, TSW1, TSW2 are switched into a second position, so that signal paths between the multiplexer switches RSW1 and RSW2
30 and, respectively, between TSW1 and TSW2 take place via said second radio frequency filters RF2 and TF2.

As explained above, between the receiving branch RX and the transmitting branch TX there is arranged a receive/transmit switch RTSW, being actuated by
35 a receive/transmit control signal RTCS. The purpose of said receive/transmit control signal RTCS is to switch, depending on the status of said receive/transmit control signal RTCS, a carrier signal output from the oscillator CS ei-

1 ther to said demodulator RSW in the receiving branch RX or to said modulator
TSW in the transmitting branch TX. Whereas one of two outputs of said receive/
transmit switch RTSW is directly connected to said demodulator RSW in the
receiving branch RX, the other output of said receive/transmit switch RTSW is
5 connected to said modulator TSW in the transmitting branch TX via the first ad-
ditional switch SW1 which is also controlled by the receive/transmit control
signal RTCS as well as the second additional switch SW2 which is arranged
between said modulator TSW in the transmitting branch TX and the input of the
transmitting branch TX, where the signal to be transmitted is fed to the
10 transmitting branch TX.

Operation of and purpose for said two additional switches SW1, SW2 are as
follows: each of said two additional switches SW1, SW2 is switchable into a
state, where their conducting paths are connected to loads, in Fig. 4 indicated as
15 resistors. The reason for this is that in receiving mode there occurs leakage of a
received signal from an antenna ANT_X associated with the transmitting branch
TX to the receiving branch RX, even though isolation between said branches RX,
TX is be very high. To attenuate this leakage, in the receiving mode said two
additional switches SW1, SW2 are switched into a state in which their
20 conducting paths are connected to said loads. But it was found that said desired
attenuation of leakage is still not enough for achieving a very high isolation
between said branches RX, TX. And also, when this conventional arrangement
operates in the transmitting mode, the signal to be transmitted (transmission, of
course, takes place by means of said transmitting branch TX) is unwantedly
25 attenuated by said second additional switch SW2 and the carrier signal output
by the oscillator CS is unwantedly attenuated by said first additional switch
SW1.

These disadvantages are overcome by an arrangement according to the present
30 invention, as already briefly described. A first embodiment is shown in Fig. 1.
The arrangement according to the present invention also comprises a receiving
branch RX and a transmitting branch TX identical to the receiving branch RX
and transmitting branch TX of the conventional arrangement.

35 However, according to the present invention the first and second additional
switches SW1, SW2 of said conventional arrangement as well as the loads con-
nected thereto are omitted.

- 1 A receive/transmit switch RTSW is directly connected between the demodulator RSW of the receiving branch RX, the modulator TSW of the transmitting branch TX, and the oscillator CS outputting the carrier signal, respectively. Said receive/transmit switch RTSW is controlled by a receive/transmit control signal
- 5 RTCS, just as it is the case with the conventional arrangement. Additionally to said conventional arrangement, the arrangement according to the present invention comprises a receive/transmit filter selector RTFS comprising two inputs. To a first input said receive/transmit control signal RTCS is applied. To a second input a primary band selection signal BSS is applied, which is the
- 10 same signal as the band selection signal BSS shown in the conventional arrangement. Said receive/transmit filter selector RTFS outputs a first and a second secondary band selection signal BSS1 and BSS2, both of said band selection signals BSS1, BSS2 being derived from said receive/transmit control signal RTCS and from said primary band selection signal BSS. A respective first
- 15 secondary band selection signal BSS1 is fed to said pair of multiplexer switches RSW1, RSW2 of said receiving branch RX. The second secondary band selection signals BSS2 is fed to said pair of multiplexer switches TSW1, TSW2 of said transmitting branch TX.
- 20 The operation of the arrangement according to the present invention is, when being in said receiving state, as follows:

When, in a first case, a signal having a frequency being within a given first frequency band is to be received within said receiving branch RX via an antenna

25 ANRX associated with said receiving branch RX, said receive/transmit filter selector RTFS generates said first secondary band selection signal BSS1 on basis of said receive/transmit control signal RTCS and said primary band selection signal BSS so that said pair of multiplexer switches RSW1, RSW2 in said receiving branch RX are switched into a first position so that the signal received

30 via said antenna ANRX passes through said first radio frequency filter RF1 of said receiving branch RX. This radio frequency filter RF1 has a passband function adjusted to said first frequency band.

At the same time, said receive/transmit filter selector RTFS generates said sec-

35 ond secondary band selection signal BSS2 on basis of said receive/transmit control signal RTCS and said primary band selection signal BSS so that said pair of multiplexer switches TSW1, TSW2 in said transmitting branch TX are

- 1 switched into a second position so that there is a kind of signal path through
said second radio frequency filter TF2 of said transmitting branch TX. Said
second radio frequency filter TF2 also has a passband function adjusted to a
second frequency band different to said first frequency band, therefore it has a
5 stop band function at said first frequency band.

Therefore, when the arrangement according to the present invention is operated
in the receiving mode and if said signal to be received by said receiving branch
RX via said antenna ANRX also would be received by said transmitting branch
10 TX via said antenna ANTXX associated with said transmitting branch TX, said
signal cannot pass through said transmitting branch TX and thereby causing
leakage to said receiving branch RX via the modulator TSW and the demodulator
RSW and said receive/transmit switch RTSW, because it is blocked by said
second radio frequency filter TF2, as said second radio frequency filter TF2 has a
15 stop band function, which does not fit with the frequency band of the signal re-
ceived.

It is easy to understand that, in a second case, if within the receiving branch RX
a signal is to be received, the frequency of which being within the range of a
20 second frequency band, the pair of multiplexer switches RSW1, RSW2 in the
receiving branch RX is switched by said first secondary band selection signal
BSS1 in such a way, that the signal passes through said second radio frequency
filter RF2, which is responsible for said second frequency band. At the same
time, said pair of multiplexer switches TSW1, TSW2 within said transmitting
25 branch TX is switched by said second secondary band selection signal BSS2 into
a state where a connection between these multiplexer switches TSW1, TSW2 is
accomplished via said first radio frequency filter TF1 of said transmitting branch
TX. The effect achieved by this is the same as achieved within the previous
described example: The signal to be received by the receiving branch RX is
30 received and fed through said receiving branch RX, whereby, when this one and
the same signal is also received by said transmitting branch TX (via its
associated antenna ANTXX), this signal is blocked within said first radio
frequency filter TF1 of said branch RX by (said) appropriate switching of said
multiplexer switches TSW1, TSW2 of said transmitting branch TX.

35

Fig. 2 shows, partially, a second embodiment of the present invention. The
elements shown in Fig. 2 may be arranged either within said receiving branch

1 RX or within said transmitting branch TX. This is demonstrated by using
reference symbols being associated either with said receiving branch RX or with
said transmitting branch TX, separated from each other by a semicolon, respec-
tively. Fig. 2 shows the combination of a pair of multiplexer switches RSW1,
5 RSW2 (or: TSW1, TSW2, respectively) with a set of three radio frequency filters
RF1, RF2, RF3 (or: TF1, TF2, TF3, respectively). Each of said multiplexer
switches RSW1, RSW2 (or: TSW1, TSW2, respectively) is actuated by one and the
same of a respective one of said secondary band selection signals BSS1, BSS2.
Each of said secondary band selection signals BSS1, BSS2 comprises
10 information about which of said radio frequency filters RF1, RF2, RF3 (or: TF1,
TF2, TF3, respectively) has to be switched between said set of multiplexer
switches RSW1, RSW2 (or: TSW1, TSW2, respectively). The further operation of
this second embodiment is just as it is with the first embodiment, already de-
scribed, i.e. in the receiving state a radio frequency filter TF1, TF2, TF3 is se-
15 lected to be switched into the transmitting path of the transmitting branch TX
with a different passband than that of the radio frequency filter RF1, RF2, RF3
selected to be switched into the transmitting path of the receiving branch RX.

Fig. 3 shows, partially, a third embodiment of the present invention. The
20 elements shown in Fig. 3 may be arranged either within said receiving branch
RX or within said transmitting branch TX. This is demonstrated by using
reference symbols being associated either with said receiving branch RX or with
said transmitting branch TX, separated from each other by a semicolon, respec-
tively. Fig. 3 shows the combination of two pairs of multiplexer switches RSW1₁,
25 RSW1₂, RSW2₁, RSW2₂, (or: TSW1₁, TSW1₂, TSW2₁, TSW2₂, respectively) with a
set of three radio frequency filters RF1, RF2, RF3 (or: TF1, TF2, TF3,
respectively). Additionally to said secondary band selection signals BSS1, BSS2
there is provided an additional pair of secondary band selection signals BSS1₁,
BSS2₁, also being generated by said receive/transmit filter selector RTFS. Each
30 pair of said multiplexer switches RSW1₁, RSW1₂, RSW2₁, RSW2₂, (or: TSW1₁,
TSW1₂, TSW2₁, TSW2₂, respectively) is actuated either by one and the same of a
respective one of said secondary band selection signals BSS1, BSS2 or by one of
said additional pair of secondary band selection signals BSS1₁, BSS2₁. Each of
said secondary band selection signals BSS1, BSS2, BSS1₁, BSS2₁ comprises
35 information about which of said radio frequency filters RF1, RF2, RF3 (or: TF1,
TF2, TF3, respectively) has to be switched between said set of multiplexer
switches RSW1₁, RSW1₂, RSW2₁, RSW2₂, (or: TSW1₁, TSW1₂, TSW2₁, TSW2₂,

1 respectively). The further operation of this third embodiment is just as it is with
the first and second embodiments, already described.

In this manner it is possible to design also multiband radio systems with more
5 that three radio frequency filters in the receiving branch RX and the transmitting
branch TX, respectively.

Furthermore, a high frequency multiband radio system according to the present
invention which comprises a receiving branch RX and a transmitting branch TX
10 respectively supporting more than one different frequency band, and a receiving/
transmitting filter selector RTFS might control radio frequency filters included
within said receiving branch RX and said transmitting branch TX, respectively,
in receiving mode also in another way so that radio signals of a frequency band
which are passed through in the receiving branch RX are blocked in the trans-
15 mitting branch TX.

For example, the support of different frequency bands might be realized by way
of switchable filters which passbands and stop bands are switchable instead of
the selection of a respective one of several filters, in which case the filter in the
20 transmitting branch TX is switched to have its stop band in the range of the
passband of the filter in the receiving branch RX during reception.

Further, the passband and the stop band(s) of the receiving branch (RX) and the
transmitting branch (TX) might be selected by way of selecting one or more seri-
25 ally connected filters, in which case the filters in the transmitting branch TX are
switched to have their stop band in the range of the passband of the filters in
the receiving branch RX during reception.

Furthermore, a combination of the above and/or other possibilities to select dif-
30 ferent bands are applicable to the invention, since the teaching of the invention
to select the filters in the transmitting branch TX to have their stop band in the
range of the passband of the filters in the receiving branch RX during reception
can be fulfilled in all cases.